



National Aeronautics and Space Administration

The Establishment of a New Friction Stir Welding Process Development Facility at NASA/MSFC



Full-Scale Manufacturing Development



- ◆ The Advanced Weld Development Facility in building 4755 is the focal point for all full-scale component, tooling, and assembly process development
 - Development includes all component, weld schedules, tooling, fixtures, and assembly processes for production hardware.
- ◆ The primary objective of full scale development is to mitigate scale-up issues before the vehicle ever reaches production and verify assembly design models
 - ◆ Only at full scale can the true challenges associated with production be identified and dealt with.
 - ◆ Also, only at full scale can the delta shift between lab and subscale hardware manufacture and assembly be assessed.
- ◆ 40+ years of experience in launch vehicle development has proven time and again that as much manufacturing development as possible must be performed at full scale—for example:
 - ◆ Material properties can vary
 - ◆ Machining and forming issues can arise
 - ◆ Increased heat-sink of large components can cause weld property variations that often require modifications to tooling and/or weld process parameters.
 - ◆ Fit up and assembly processes need to be solved prior to production



18-Foot Diameter 1-piece Y-Ring

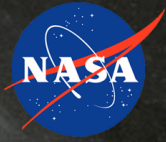


Barrel panel prep on Vertical Weld Tool



Spin formed dome 1st article cut up

Tools and Equipment Required for Manufacturing Development Article (MDA) Assembly



RWT

- ◆ **The Robotic Weld Tool (RWT)**
 - 7-axis robot capable of performing both Self Reacting and Conventional FSW on complex curvature tank structures up to Ares V size
- ◆ **Fixtures for the Robotic Weld Tool**
 - Used to hold and position components on the RWT turntable.
- ◆ **Process Development System (PDS)**
 - Used for panel-level development.
- ◆ **The Morton Table Tool (MTT)**
 - Used to close-out Self Reacting Friction Stir Welds using Friction Pull Plug Welding.
 - Also used to perform fusion seal weld on Common Bulkhead assembly.
- ◆ **The Vertical Weld Tool (VWT)**
 - Designed to accommodate assembly of barrel sections up to Ares V size
- ◆ **Vertical Trim Tool (VTT)**
 - Necessary to trim completed tank barrel sections to length.

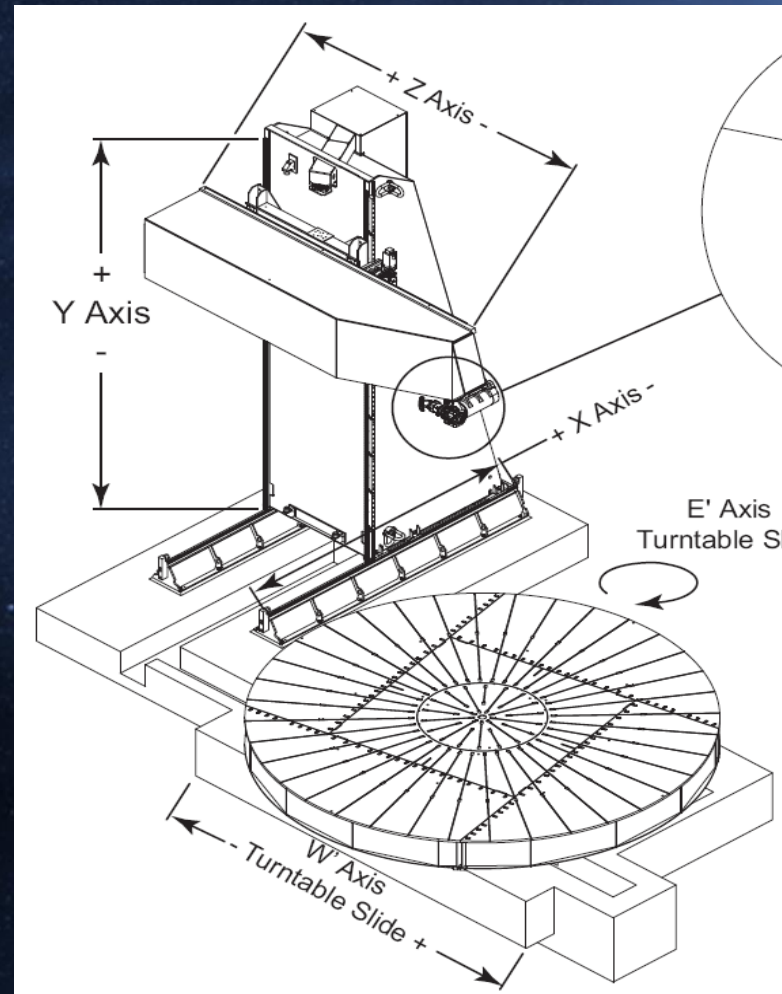


VWT

The Robotic Weld Tool



- ◆ Supplied by MTS Systems Corporation.
- ◆ 7-axis machine tool capable of making both conventional and self-reacting friction stir welds in complex (e.g. not linear) weld joints.
- ◆ 3-axis horizontal traveling column with retractable boom
- ◆ 2-axis roll and pitch assembly positioned on the end of the boom
- ◆ Rotary turntable that can both slew and slide.



Vertical Weld Tool (VWT)



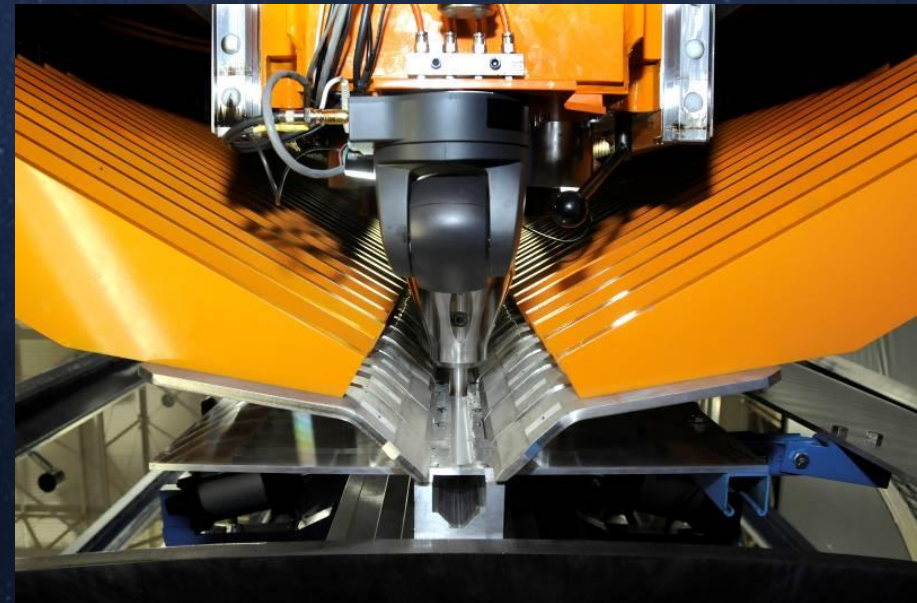
- ◆ Mechanical systems provided by Transformation Technologies Inc. (now Manufacturing Technologies Inc.)
- ◆ Control system and integration by Lockheed Martin Huntsville Technical Operations.
- ◆ Designed to assemble full-scale cylindrical barrel sections.
 - **Can accommodate barrels up to Ares V size.**
- ◆ Capability of both conventional and self reacting FSW.



VWT Clamping System



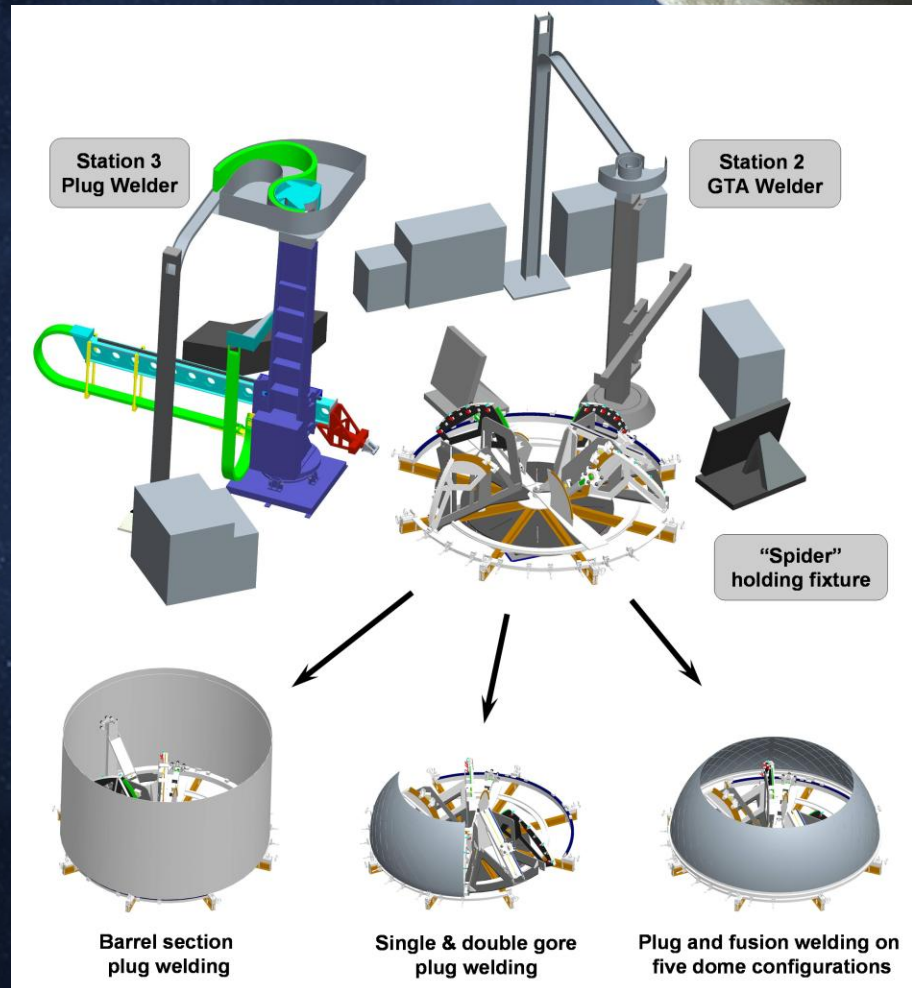
- ◆ 148 pneumatically actuated clamps.
- ◆ Each clamp uses a 3 inch long clamp foot.



Morton Table Tool (MTT)

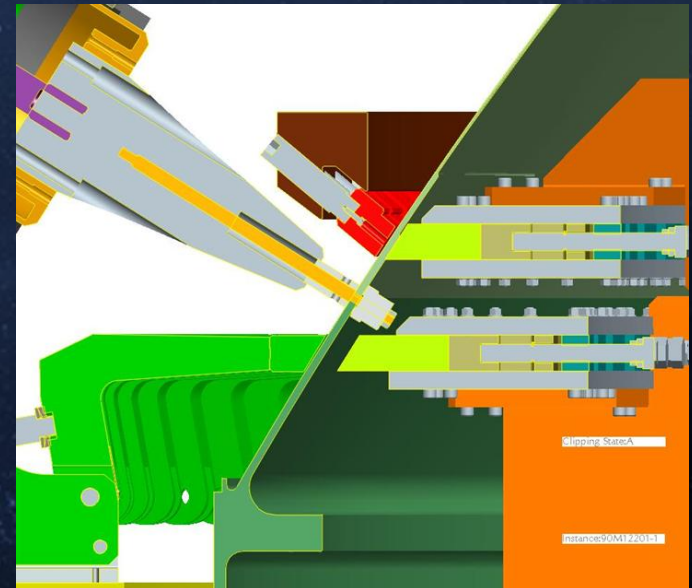
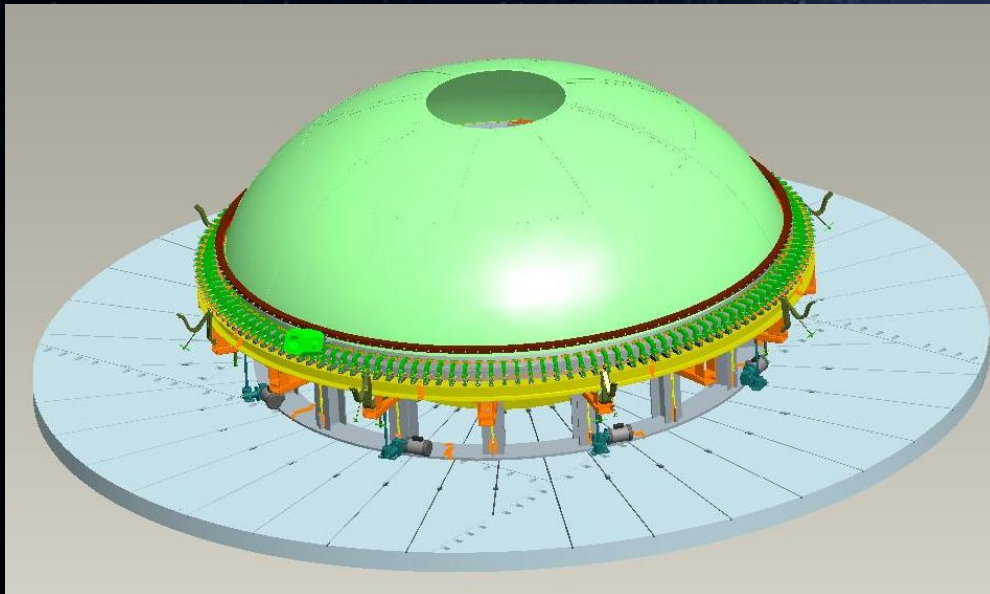


- ◆ Multi-purpose station for performing friction pull plug welds and gas tungsten arc welds on Ares I upper stage gores, domes, and barrels.
- ◆ Will perform plug welding close-out in circular and circumferential Self Reacting welds.
- ◆ Also will be used to perform a GTA seal weld on the Common Bulkhead.



Y-Ring Welding Fixture

- ◆ Used for SR-FSW of Y-Ring to dome body.
- ◆ Two internal mandrels, one located on each side of the joint .
- ◆ Two external clamping rings, one located on each side of the joint.
- ◆ Designed to allow the y-ring to be moved up and down relative to, and coaxial with, the dome body.
 - **Allows the weld joint to be separated for trimming and pre-weld preparation, and then mated for welding.**



Full Scale Component Development



- ◆ **Full-scale component development allows establishment and qualification of production requirements, and production vendors.**
 - Forming processes
 - Machining processes
 - Material property data
 - Material Certification/Quality Requirements—including specifications
 - Process and Quality controls
 - NDE process
- ◆ **Components include but not limited to gores, spin formed domes, ring forgings, dome caps, and barrel panels.**
- ◆ **Required prior to procurement and design of production hardware**



Forming of Gores



Spin Formed Dome 1st Article



18-Foot Diameter 1-piece Y-Ring

Synergy with Michoud Assembly Facility (MAF)

Production Operations

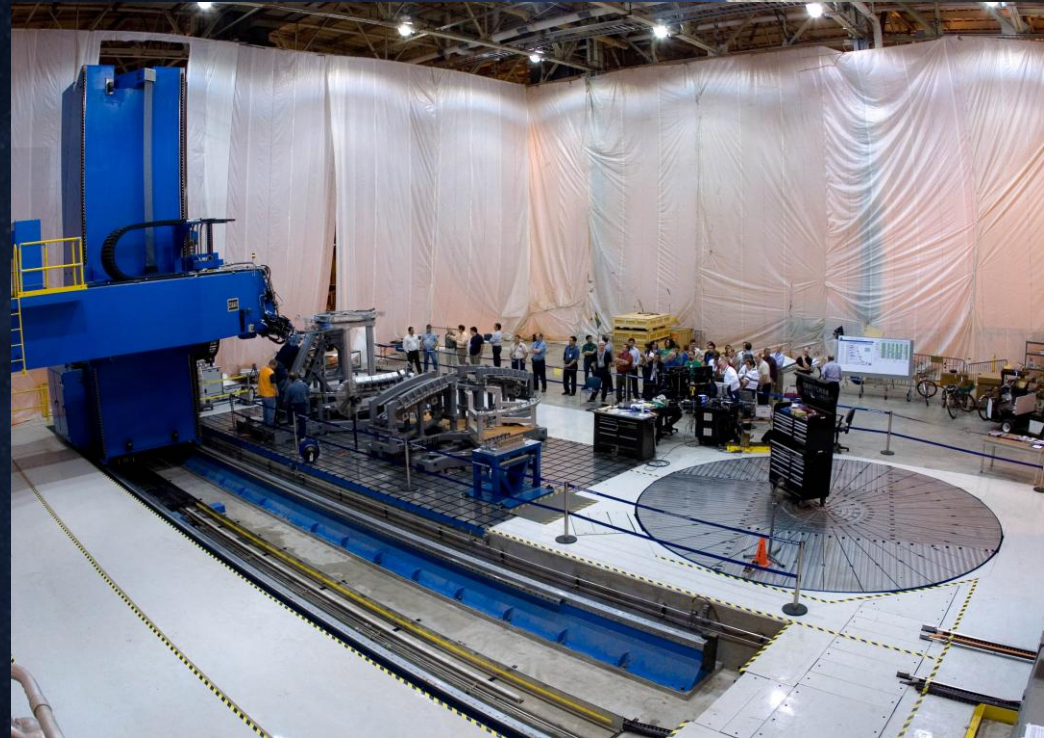


◆ Production tool and fixture requirements are baselined in 4755.

- Development operations in 4755 are approximately 2-years ahead of Ares I production operations. Thus, we have the ability to develop and test tool and fixture concepts, identify deficiencies, and improve requirements for production tooling.
- Further, we develop tool and fixture suppliers and work supplier issues ahead of production procurements.

◆ Examples:

- The MAF UWS was procured using the MSFC RWT requirements with a 2-page addendum.
- At MSFC we had approximately 1-year of technical difficulties when bringing the RWT online.
- Bad for us, but good for the overall program - we worked the bugs out at MSFC and saved Orion production about 1-year of schedule.

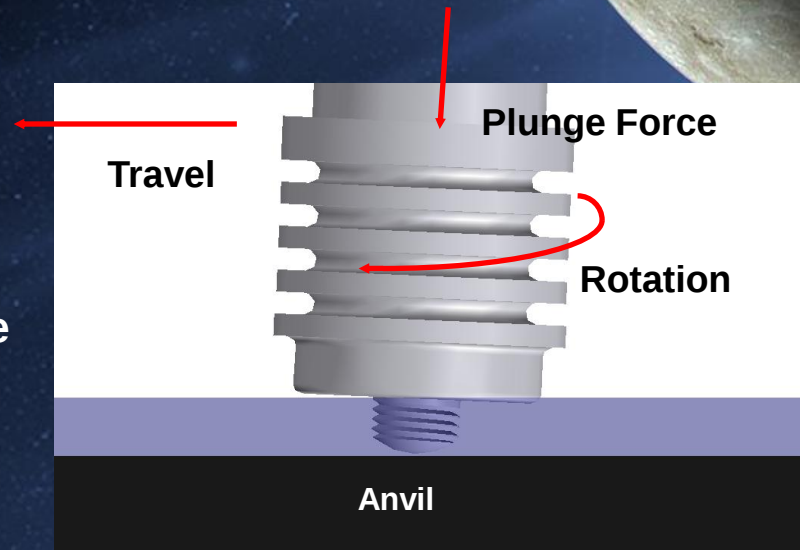


Universal Welding System at MAF being used for Orion Production. This tool was patterned after the MSFC RWT.

Friction Stir Welding

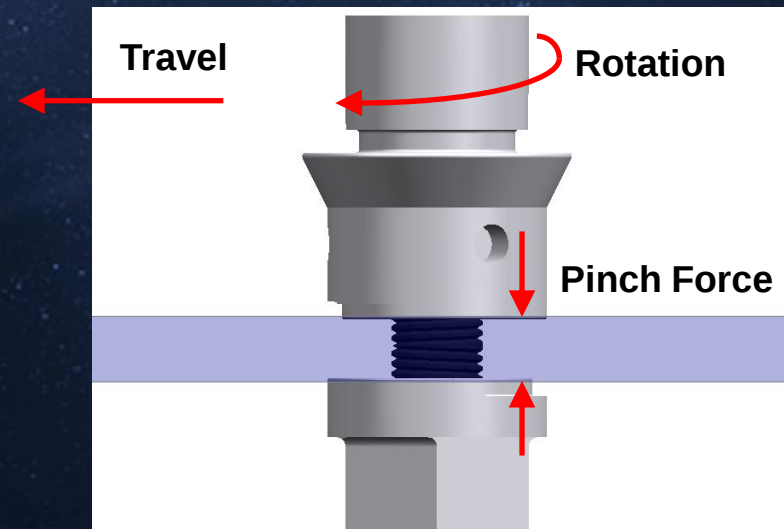
Conventional FSW:

- Used in ET Production
- Solid State Process
- Uses Non-Consumable Rotating Tool
- Rotating tool is plunged into work piece until the tool shoulder is in contact with the workpiece. Tool then traverses along the weld joint. At end of weld joint the tool is withdrawn from the workpiece.



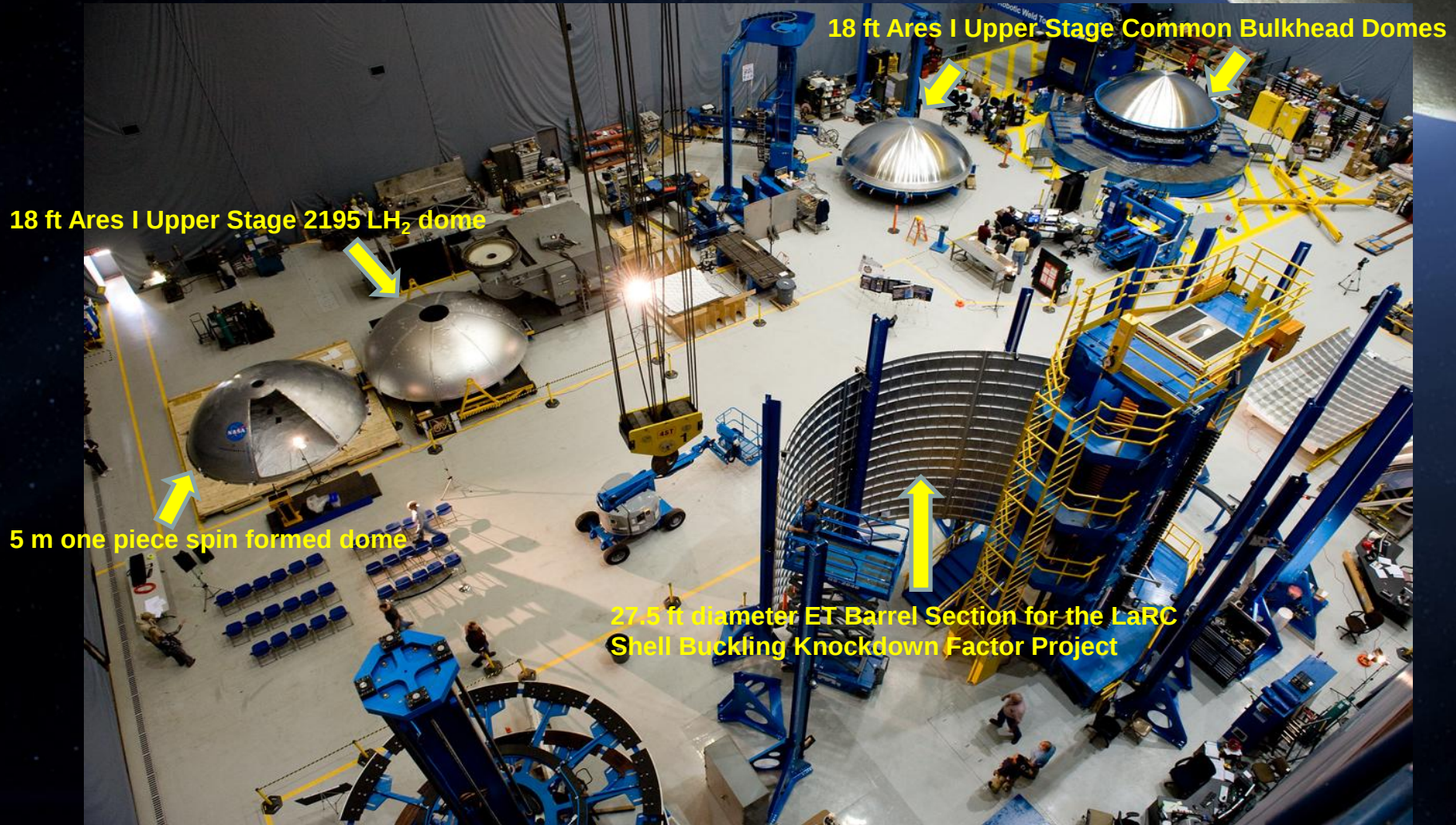
Self Reacting FSW:

- No Anvil Required
- Rotating tool "pinches" the work piece between two shoulders and traverses along the weld joint.





Full-scale Process Development and Manufacturing Demonstration



18 ft Ares I Upper Stage Common Bulkhead Domes

18 ft Ares I Upper Stage 2195 LH₂ dome

5 m one piece spin formed dome

27.5 ft diameter ET Barrel Section for the LaRC
Shell Buckling Knockdown Factor Project